APPARATUS AND METHOD FOR MELT SPINNING A SYNTHETIC YARN

Cross Reference to Related Application

The present application is a continuation of copending international application Serial No. PCT/EP99/05203, filed 21 July 1999 and designating the USA.

Background of the Invention

The invention relates to an apparatus and method for melt spinning a synthetic yarn.

EP 0 682 720 and corresponding U.S. Patent No. 5,976,431 disclose a melt spinning apparatus and method wherein freshly extruded filaments are advanced in a cooling tube with a vacuum atmosphere. The cooling tube is arranged at a distance from the spinneret, so that an air stream develops in the cooling tube for cooling the filaments in the direction of the advancing yarn. In this connection, the flow velocity of the air and the spinning speed are adapted to each other such that the air stream assists the filaments in their advance in the cooling tube. With that, it is accomplished that the solidification point of the filaments moves away from the spinneret. This leads to a delayed crystallization of the polymer that favorably influences the physical properties of the yarn. Thus, for example, in the production of POY yarn, it was possible to increase the withdrawal speed and, thus, the draw ratio, without changing the elongation values necessary for further processing of the yarn.

The known spinning apparatus consists of a cooling tube and a suction device downstream of the spinneret. Between the spinneret and the cooling tube, an inlet cylinder extends with a gas permeable wall. By the

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interaction of the inlet cylinder and the suction device, a quantity of air is introduced within the spin shaft and guided within the cooling tube as an accelerated air stream in the direction of the advancing yarn. As the filaments pass through the inlet cylinder, they are precooled in such a manner that an increase of viscosity in the surface layers causes the firmness of the surface layer to increase. Upon their entry into the cooling tube, the filaments are still molten in their core, so that final solidification occurs only in the cooling tube. To this end, the cooling tube consists of a funnel-shaped inlet with a narrowest cross section in the cooling tube and cylindrical portion directly adjacent thereto. The narrowest cross section and the cylindrical portion cause the air stream to accelerate such that the filaments are assisted in their advance and undergo a delayed solidification only in the cooling tube. However, in the case of coarser filament deniers, the problem arises that while the air stream entering the cooling tube assists the advance of the filaments, it will not lead to an adequate cooling of the filaments. Although the known spinning apparatus is provided with an air supply device at the inlet end of the cooling tube for generating an additional cooling stream, same leads, however, to a considerable cooling of the filaments already before the air stream is accelerated in the cooling tube, so that the positive effect of a delayed crystallization of the polymer is not effective or only inadequately effective.

It is therefore an object of the invention to improve the initially described spinning apparatus and method such that filaments with coarser deniers are adequately cooled over a short distance, even in the case

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of delayed crystallization of the polymer, and at high spinning speeds.

Summary of the Invention

The above and other objects and advantages of the invention are achieved by the provision of a melt spinning apparatus and method which includes an extruder for heating a polymeric material and extruding the resulting melt through a spinneret nozzle to form a plurality of downwardly advancing filaments. A cooling tube is disposed below the spinneret nozzle and comprises an inlet, a cylindrical portion below the inlet, and an outlet. A gas permeable inlet cylinder is positioned between the spinneret nozzle and the inlet of the cooling tube, and a suction generating device is connected to the outlet of the cooling tube so as to generate an initial cooling air stream through the cooling tube in the direction of the advancing filaments. An air supply device is provided for generating an additional cooling air stream in the cooling tube, with the air supply device being positioned downstream of the inlet of the cooling tube. Also, guide means is provided for gathering the advancing filaments to form an advancing multifilament yarn, and a winder serves to wind the advancing multifilament yarn into a package.

The invention has the advantage that the initial air stream present at the inlet end of the cooling tube serves to delay exclusively crystallization of the polymer. This ensures that the solidification point of the filaments is inside the cooling tube. For further cooling of the filaments, use is made of the additional cooling air stream that is introduced by the air supply device. To this end, this air supply device is arranged downstream of the narrowest cross section of the inlet in

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the cylindrical portion or downstream of the outlet end of the cooling tube. With that, it is accomplished that the additional cooling air stream contacts the filament bundle only shortly before or after solidification of the filaments. This influences in particular the evenness of the filament cross sections and results in a high spinning reliability and absence of lint.

In one preferred embodiment, the air supply device connects to the cooling tube so that the additional cooling air stream and the initial cooling air stream flow together in the direction of the advancing filaments. Since the two air streams are equidirectional, turbulence is essentially avoided.

In this connection, it is possible to construct the air supply device in a simple manner by an opening in the wall of the cooling tube. The cooling stream entering the cooling tube through the opening adjusts itself automatically due to the vacuum atmosphere in the cooling tube.

A further development of the invention provides that the air stream entering at the inlet end of the cooling tube and the additional cooling air stream entering the cooling tube through the opening are adjustable independently of each other. To this end, the air supply device comprises an air stream generator that generates the additional cooling air stream. The air stream generator could be, for example, a blower.

In a particularly advantageous embodiment of the spinning apparatus, the air stream generator is constructed as an injector with a nozzle bore that connects to a source of compressed air. In this arrangement, the nozzle bore of the injector terminates directly in the opening in the wall of the cooling tube. Also, the center axis of the cooling tube and the nozzle

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bore form an acute angle in direction of the advancing yarn, so as to introduce into the cooling tube the additional cooling air stream so as to have a directional component in direction of the advancing yarn. Such a configuration of the spinning apparatus is also suitable in particular for threading the filaments into the cooling tube at the start of the process. An angle range from 15°C to 30°C further provides that in the region of the cooling air stream the filament bundle is safely kept off the wall of the cooling tube.

To adjust the cooling air stream as a function of the filament type and filament denier, the free flow cross section of the opening may be adjustable by means of a sleeve mounted on the cooling tube, and which is arranged for movement along the cooling tube for closing the opening in full or in part.

In an advantageous further development, the adjustment device may comprise an air chamber enclosing the opening in the cooling tube on the outside. This air chamber has a supply line with a throttling device. Thus, it is possible to control the air supply to the air chamber by means of the throttling device in the supply line.

To achieve with the cooling stream a most intensive possible cooling, it is possible to connect the supply line of the air chamber to the air stream generator.

In the above embodiments, the opening arranged in the wall of the cooling tube may be made as a bore or a radial cutout. In a particularly advantageous further development of the spinning apparatus, the opening is formed by an annular, perforated sheet element in the wall of the cooling tube. In this instance, the perforated sheet element extends about the entire circumference of the cooling tube. This ensures a

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uniform inflow of the cooling air stream into the cooling tube. The plurality of holes permits a flow to be generated that has little turbulence.

The perforated sheet element may be made conical with a cross section increasing in direction of the advancing yarn and arranged in the extension of the cooling tube at the outlet end thereof. With that, cooling of the filaments is further intensified since the expansion of the air stream effects a better mixing between the initial cooling air stream and the additional air stream.

Besides a very intensive cooling, a particularly advantageous further development facilitates a preliminary drawing of the filaments. Here, the additional cooling air stream is oppositely directed to the direction of the advancing yarn and generates on the filaments a frictional force that acts against the direction of the advancing yarn. This frictional force effects a drawing of the filaments.

In another embodiment, the air supply device is constructed such that the suction device can generate the additional cooling air stream. To this end, a second cooling tube connects as an extension to the first cooling tube directly to the outlet chamber of the suction device.

To equalize the flow, it is preferred to construct the second cooling tube with a funnel-shaped inlet and a cylindrical outlet with an air-permeable wall.

To increase the draw effect in the case of such an air supply device, the cooling tube could include a heating device.

The method of the present invention is characterized in particular in that it permits production of textile or industrial yarns of polyester, polyamide, or

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polypropylene with coarse deniers and high elongation values. The method may be coupled with different treatment devices, so that, for example, fully drawn yarns, partially oriented yarns, or highly oriented yarn can be produced.

<u>Brief Description of the Drawings</u>

In the following, several embodiments of the melt spinning apparatus according to the invention are described in more detail with reference to the accompanying schematic drawings, in which:

Figure 1 illustrates a first embodiment of a spinning apparatus according to the invention with a takeup device downstream thereof;

Figure 2 illustrates a further embodiment of a spinning apparatus according to the invention with an air supply device arranged on the cooling tube;

Figure 3 illustrates a further embodiment of an air supply device; and

Figures 4 and 5 illustrate further embodiments of the spinning apparatus according to the invention with an air supply device.

<u>Detailed Description of the Preferred Embodiments</u>

Figure 1 shows a first embodiment of an apparatus for spinning a synthetic yarn according to the invention. As illustrated, a yarn **12** is spun from a heated thermoplastic material. To this end, an extruder or a pump melts the thermoplastic material, and a spin pump delivers the melt via a melt line **3** to a heated spin head **1**. The underside of spin head **1** mounts a spinneret nozzle **2**. From the spinneret nozzle **2**, the melt emerges in the form of fine filament strands **5**, which advance as a filament bundle through a spin shaft **6** that includes an

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inlet cylinder **4** which is formed by a perforated wall **7**. To this end, the inlet cylinder **4** is positioned directly downstream of spin head **1** and surrounds the filaments **5**.

In the direction of the advancing yarn, a cooling tube **8** connects to the bottom free end of inlet cylinder **4**. At the inlet end, the cooling tube **8** comprises an inlet **9**, which is preferably funnel-shaped and connects to the inlet cylinder **4**. In the narrowest cross section of inlet **9**, the cooling tube **8** comprises a second, cylindrical portion **32**. At the end of cylindrical portion **32**, the cooling tube **8** comprises an outlet cone **10** that forms an outlet **33**. The outlet cone **10** terminates in an outlet chamber **11**. On its underside, the outlet chamber **11** mounts an air supply device **34**, which includes a second cooling tube **35**. From the underside of outlet chamber **11**, the second cooling tube **35** extends coaxial with the first cooling tube **8**. At its inlet end, the second cooling tube **35** comprises a funnel-shaped inlet **36** that connects to the outlet chamber **11**. The free end of the second cooling tube **35** forms a cylindrical outlet **37** which has a gas permeable wall. The outlet comprises at its bottom end an outlet opening **13**, from which the filaments **5** emerge.

A suction line **14** terminates in suction chamber **11** on one side thereof. Via suction line **14**, a suction device **15** arranged at the free end of suction line **14** connects to outlet chamber **11**. The suction device **15** may comprise, for example, a vacuum pump or a blower that generates a vacuum in outlet chamber **11** and, thus, in the first cooling tube **8** and in the second cooling tube **35**. Between the outlet **33** of the first cooling tube and the inlet **36** of the second cooling tube **35**, the outlet chamber **11** accommodates a screen cylinder **30** that

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surrounds the filaments **5**. The screen cylinder **30** has an air permeable wall.

In the plane of the advancing yarn downstream of the air supply device **34**, a lubrication device **16** and a takeup device **20** are arranged. The takeup device **20** includes a yarn guide **19**. The yarn guide **19** indicates the start of a traversing triangle that results from the reciprocal movement of a traversing yarn guide of a yarn traversing device **21**. Downstream of the yarn traversing device **21**, a contact roll **22** is arranged. The contact roll **22** lies against the circumference of a package **23** that is to be wound. The package **23** is wound on a rotating winding spindle **24**. To this end, a spindle motor **25** drives the winding spindle **24**. The drive of the winding spindle **25** is controlled as a function of the rotational speed of the contact roll such that the circumferential speed of the package and, thus, the winding speed remain substantially constant during the winding operation.

Between the lubrication device **16** and the takeup device **20**, a treatment device **17** is arranged for treating the yarn **12**. In the embodiment shown in Figure 1, an entanglement nozzle **18** forms the treatment device **17**.

As a function of the production process, it is possible to arrange in the treatment device one or more heated or unheated godets, so that the yarn is drawn before being wound. There is likewise a possibility of arranging additional heating devices for drawing or relaxing within the treatment zone **17**.

In the spinning apparatus shown in Figure 1, a polymer melt is delivered to the spin head **1** and extruded through spinneret nozzle **2** to form a plurality of downwardly advancing filaments **5**. The filament bundle is withdrawn by the takeup device **20**. In this process, the

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filament bundle advances at an increasing speed through spin shaft **6** within inlet cylinder **4**. Subsequently, the filament bundle enters cooling tube **8** through the funnel-shaped inlet **9**. In the cooling tube **8**, suction device **15** generates a vacuum. Ambient air outside of inlet cylinder **4** is thereby sucked into spin shaft **6**. The air entering spin shaft **6** is proportional to the gas permeability of the wall **7** of inlet cylinder **4**. The inflowing air leads to a precooling of the filaments, so that their surface layers firm up. In their core, however, the filaments remain molten. The quantity of air is then sucked together with the filament bundle through inlet **9** into cooling tube **8**. The air stream is accelerated due to the narrowest cross section formed at the end of inlet **9** and the action of suction device **15** such that an air stream counteracting the movement of the filaments is no longer present in the cooling tube. The narrowest cross section extends over the entire region of cylindrical tube portion **32**. Thus, the length of cylindrical tube portion **32** defines the acceleration distance within cooling tube **8**. In this connection, the cylindrical tube portion may have a length from few millimeters to 500 mm or greater. The air stream in the direction of the advancing yarn decreases the stress on the filaments, and the solidification point moves away from the spinneret. It is thus possible to influence the relationship between spinning speed and drawing during the production of the yarn such that high elongation values are obtained despite high spinning speeds. Within the cooling tube **8**, the filaments undergo a cooling.

For a further cooling, the air supply device generates an additional cooling air stream. To this end, the filaments advance through the second cooling tube **35** downstream of first cooling tube **8**. The outlet cone **10**

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of the first cooling tube and the funnel-shaped inlet **36** of the second cooling tube **35** both terminate in the outlet chamber **11**. The air stream from cooling tube **8** and the additional cooling air stream from cooling tube **35** are sucked under the action of suction device **15** into the outlet chamber **11**. They exit therefrom via screen cylinder **30** through suction line **14**. Thereafter, the entire air stream is removed by suction device **15**.

On the outlet side of cooling tube **35**, the filaments **5** emerge from outlet opening **13**, and enter the lubrication device **16**, which combines the filaments to a yarn **12**. To increase cohesion, the yarn **12** is entangled in an entanglement nozzle **18** before being wound. In the takeup device, the yarn **12** is wound to a package **23**.

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~~It is possible to use the arrangement shown in Figure 1 to produce, for example, a polyester yarn that is wound at a takeup speed greater than 7,000 m/min. The spinning apparatus of Figure 1 is characterized in that the air quantity entering the inlet cylinder is adapted to the delayed heat treatment of the filaments. In this connection, it is possible to influence with advantage both precooling and delayed solidification of the filaments. The final cooling of the filaments occurs in a second zone that is formed by the second cooling tube **35**. To intensify the cooling, it would be possible to supplement air supply device **35** with an air stream generator that could connect to the outlet end of the second cooling tube **35**.~~

Figure 2 shows a further embodiment of a spinning apparatus according to the invention, wherein an air supply device **34** with an air stream generator **38** is provided.

The spinning apparatus shown in Figure 2 differs from the embodiment shown in Figure 1 by the

configuration of the air supply device **34**. Therefore, as regards the description of the remaining structural elements that are indicated by identical numerals, the description of the embodiment of Figure 1 is herewith incorporated by reference.

In the embodiment of the spinning apparatus as shown in Figure 2, the air supply device **34** is arranged in the region of the cylindrical portion **32** of the cooling tube **8**. To this end, the cooling tube **8** comprises an opening **39** in the wall of cylindrical tube portion **32**. The opening **39** is formed by an annular, perforated sheet element **40** that is inserted into the wall of cylindrical tube portion **32**. The opening **39** in the wall of cylindrical tube portion **32** is enclosed by an air chamber **42** externally surrounding the wall of cylindrical tube portion **32**. The air chamber **42** is connected to a supply line **41**, which in turn connects to an air stream generator **38**. Between air stream generator **38** and air chamber **42**, the supply line **41** accommodates an adjustable throttle **44**, which is adapted for controlling the free flow cross section of supply line **41**.

In the embodiment of the spinning apparatus according to the invention as shown in Figure 2, the additional air stream is generated by the interaction of suction device **15** and air stream generator **38** of air supply device **34**. In this arrangement, the additional cooling air stream enters the acceleration length of cooling tube **8** through opening **39**. To avoid turbulence inside the cooling tube **8**, the cooling air stream enters opening **39** through a plurality of perforations of the perforated sheet element **40**. The additional cooling air stream and the initial air stream mix and flow in the direction of the advancing yarn to the outlet **33** of cooling tube **8**. There, the additional cooling air stream

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and the air stream enter outlet chamber **11**, and are removed by suction device **15** via suction line **14**. The filament bundle is cooled inside cooling tube **8**. On the underside of outlet chamber **11**, the filament bundle leaves the cooling zone through the outlet opening **13**. Subsequently, a lubrication device **16** combines the filament bundle to the yarn.

The embodiment shown in Figure 2 is characterized in that an intense cooling can occur within the cooling tube despite a delayed cooling and, thus, the relocation of the solidification point.

The air stream entering at inlet **9** of cooling tube **8** and the position of the air supply device **34** on the cooling tube are adapted such that the additional cooling air stream enters the cooling tube **8** shortly before or shortly after the solidification point of the filaments. Thus, a relatively great uniformity is accomplished in the formation of the filaments or yarn.

An opening that is locally defined on the circumference may also form the air supply device **34**. Likewise, it is possible to construct the air supply device **34** without air stream generator **38**, so that ambient air is able to enter directly the air chamber **42**, via supply line **41**, due to the action of suction device **15**.

Figure 3 shows a modification of the air supply device **34**, as could be used, for example, in the spinning apparatus of Figure 2. In this embodiment, an axially slidable sleeve **43** covers the openings **39** in the perforated sheet element **40**. The portion of openings **39** that are not covered by sleeve **43** connects to the ambient air. Thus, due to the vacuum atmosphere in cooling tube **8**, an additional cooling air stream will form that flows via the free flow cross section of openings **39** into the

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interior of cooling tube **8**. In direction of the advancing yarn upstream of air supply device **34**, the filaments **5** are contacted by the air stream sucked in at the inlet end of air supply device **34**, which delays cooling of the filaments. Only after the filaments **5** have passed air supply device **34**, will cooling of the filaments be intensified by the additionally inflowing cooling air stream, so that the filaments are cooled when they leave cooling tube **8**. By adjusting the sleeve **43**, it is possible to regulate the air quantity for forming the cooling air stream as a function of the yarn denier or polymer type.

Figure 4 shows a further embodiment of an air supply device **34**. The spinning apparatus is identical with the embodiment of Figure 2. To this extent, the description of Figure 2 is herewith incorporated by reference.

In the embodiment of the spinning apparatus of Figure 4, the air supply device **34** is formed at the outlet end of cooling tube **8**. To this end, the outlet cone **10** comprises a gas-permeable wall. The openings **39** in the wall of cooling tube **8** thus extend from the end of cylindrical tube portion **32** to the outlet **33**. The gas-permeable wall of outlet cone **10** is arranged inside an air chamber **42** that surrounds cooling tube **8**. The air chamber **42** comprises a supply line **41** that connects at its end to the ambient air. An adjustable throttle **44** controls the free flow cross section of supply line **41**.

In the spinning apparatus shown in Figure 4, suction device **15** generates the additional cooling air stream. In this process, the ambient air enters air chamber **42** through supply line **41**. From the air chamber **42**, the ambient air enters the cooling tube due to the vacuum atmosphere therein through the air-permeable wall of outlet cone **10**. Based on the widening cross section in

direction of the advancing yarn, an intense mixing occurs between the air stream accompanying the filaments and the laterally entering cooling air stream. This results in an intense cooling of the filaments. The cooling air stream and air stream are removed by suction device **15** through outlet chamber **11** and suction line **14**.

Figure 5 shows a further embodiment of a cooling system of a spinning apparatus. In this embodiment, the air supply device is arranged downstream of inlet **9** in the region of the cylindrical portion **32** of cooling tube **8**. To this extent, the embodiment shown in Figure 5 is identical with the embodiment shown in Figure 2, whose description is herewith incorporated by reference.

The air supply device **34** of Figure 5 comprises an opening **39** in the wall of cooling tube **8** that is constructed in the form of a bore. Furthermore, the air supply device comprises an injector **45** and a source of compressed air **47**. The source of compressed air **47** connects to a nozzle bore **46** of injector **45**. The injector **45** and the source of compressed air **47** act as an air stream generator and advance a cooling air stream through the opening **39** into the interior of cooling tube **8**. The nozzle bore **46** of injector **45** is made such that between the center axis of the cooling tube and the nozzle bore an angle < 90° forms in the direction of the advancing yarn. Thus, the cooling air stream is directed in the direction of the advancing yarn into the interior of cooling tube **8**.

Besides the cooling effect, the embodiment of the air supply device of Figure 5 has proven itself in particular for threading the filaments at the beginning of the process. The injector introduces the additional cooling air stream at a high acceleration into the interior of the cooling tube. Due to the suction effect

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of suction device **15**, this cooling air stream propagates substantially in the center region of the tube cross section. This flow entrains the filaments and guides the filament bundle reliably through cooling tube **8**. To further increase the effect, it would be possible to arrange on the opposite side of the wall a second or further air supply device with injector.

The air supply devices shown in Figures 2-4 comprise each annular openings that extend over the entire circumference of the cooling tube. However, it is also possible to limit the openings to extend only partially over a certain circumferential section of the cooling tube. It is also possible to form several openings side by side and/or one after the other in the wall of the cooling tube. The configuration of the openings or insertion of porous walls, such as for example the perforated sheet element, permit the flow of the cooling air stream to enter the interior of the cooling tube substantially without causing major turbulences. The embodiment of the air supply device shown in Figure 4 generates a flow with especially little turbulence for cooling the filaments, which increases spinning reliability or the stabilized advance of the yarn.

The invention is not limited to a certain configuration of the cooling tube. The cylindrical shapes illustrated in the embodiments are exemplary and may easily be replaced with an oval shape, or even with an angular shape of the cooling tube when rectangular spinnerets are used.

It can as well be advantageous, especially for the production of highly oriented yarns, to make the cylindrical portion of the cooling tube very short. In an extreme case the cooling tube could consist of an inlet cone and an outlet cone only, such that the air

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supply device according to the embodiment as shown in Fig. 2 would be located in the region of the outlet cone **10**.

Many modifications and other embodiments of the invention will come to mind to one skilled in the art to which this invention pertains having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the invention is not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

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